

# (12) UK Patent Application (19) GB (11) 2 136 239 A

(43) Application published 12 Sep 1984

(21) Application No 8405571

(22) Date of filing 2 Mar 1984

(30) Priority data

(31) 8305848 (32) 3 Mar 1983 (33) GB

(51) INT CL<sup>3</sup>  
H04B 9/00 G02B 5/14

(52) Domestic classification  
H4B F  
G2J GBA GBB  
U1S 2204 G2J H4B

(56) Documents cited  
GBA 2071351 GBA 2061547  
GB 1580913 GB 1475478  
US 4000416

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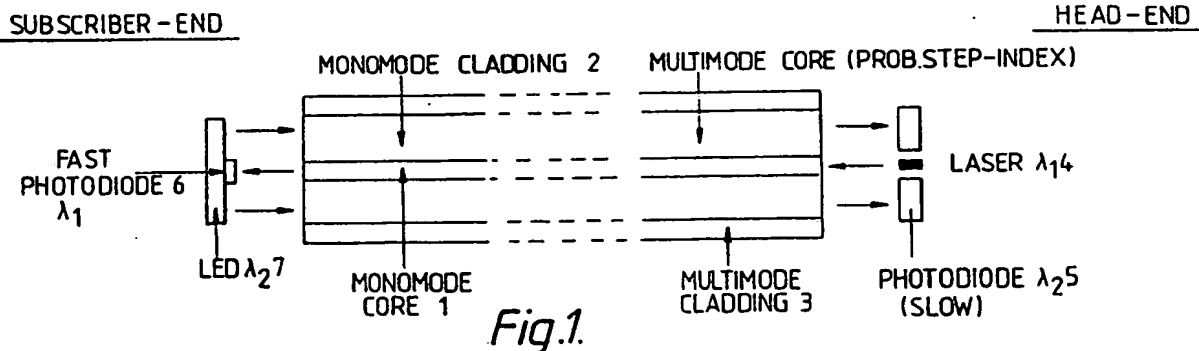
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(58) Field of search  
H4B  
G2J

## (54) Optical fibre transmission systems

(57) The wide bandwidth channel to a subscriber (4, 1, 6) of an optical fibre cable TV system, and the narrow bandwidth return channel (7, 2, 5) from the subscriber are wavelength division multiplexed over a single fibre. The wide band channel is transmitted at one wavelength ( $\lambda_1$ ) through the core (1) of the fibre, and the return channel is transmitted at another wavelength ( $\lambda_2$ ) through the cladding (2) of the core (1) which itself forms a further core by virtue of a cladding (3) surrounding it.



GB 2 136 239 A

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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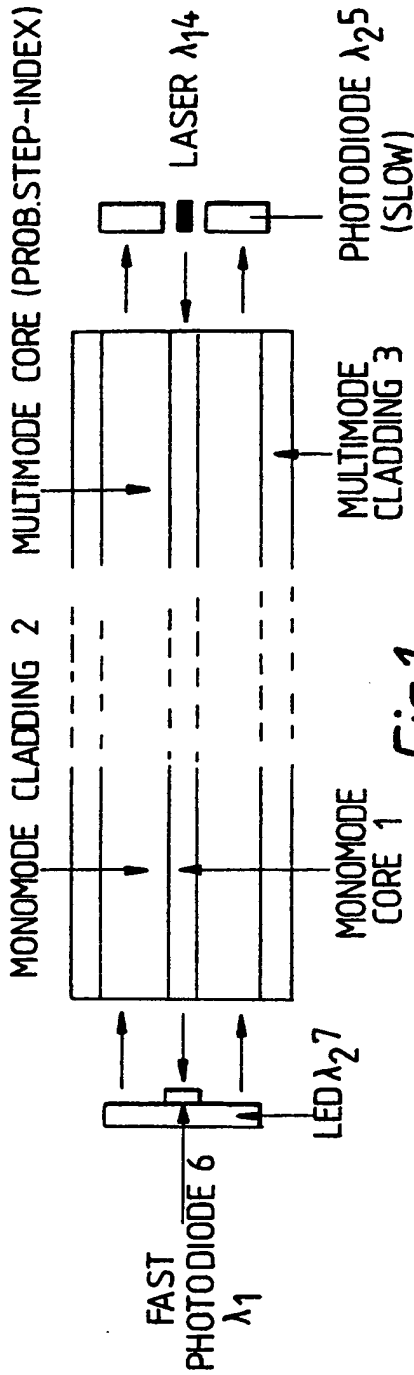


Fig. 1.

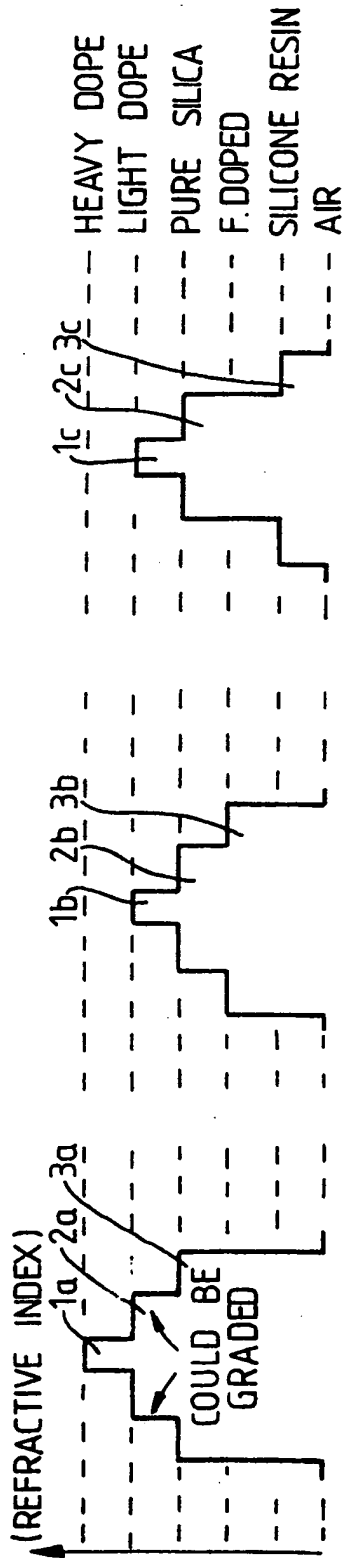


Fig. 2a.

Fig. 2b.

Fig. 2c.

Fig. 3a.

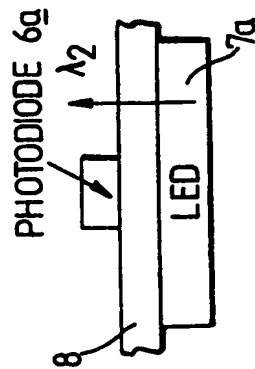


Fig. 3b.

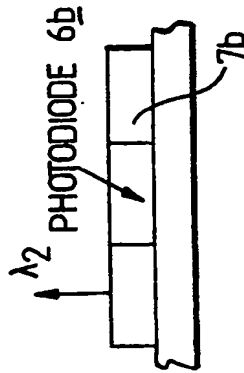


Fig. 3c.

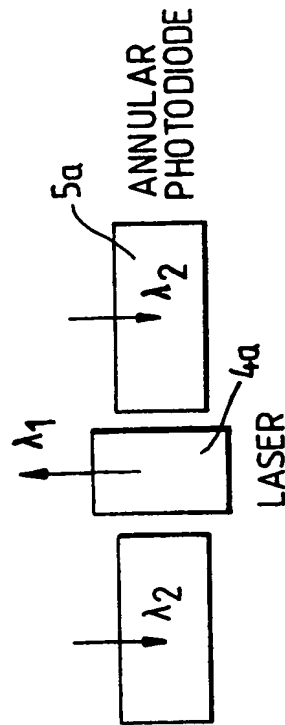
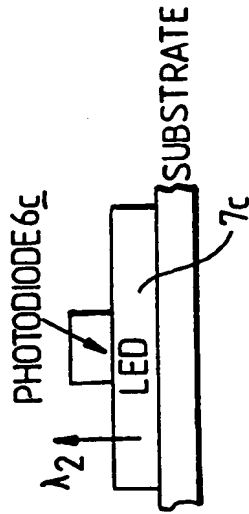


Fig. 4.

# SPECIFICATION Optical fibre transmission systems

This invention relates to optical fibres and optical fibre transmission systems.

The invention has an important application in the field of interactive cable television systems.

Interactive cable television systems are cable television systems which, in addition to one or more forward transmission channels to a subscriber include a return transmission channel from the subscriber.

A number of proposals have been made for the system arrangement for such interactive cable television systems. For example, so-called tree structured coaxial cable CATV systems which offer a return path for additional interactive services do so by frequency division multiplexing of forward and return channels. Typically, the signals in the upstream direction are combined, with terminals being polled in succession by automatic head-end equipment. The return channel bandwidth available to any one subscriber is severely limited, sometimes to only a few bits per second.

So-called star structured systems containing remote flexibility points, that is switches, may use these points as concentrators to give significantly greater return channel bandwidth. Such systems are being planned around optical fibre transmission, but it is then necessary to employ conventional wave length division multiplexing in which light of two different wave lengths is transmitted through the same fibre core, one wave length for forward and the other wave length for return transmission, or to use two fibres to provide the two paths. Also, optical fibre systems are not well suited to conventional frequency divisions multiplexing techniques.

On the other hand, fibres may account for a significant fraction of a system's costs, making the two-fibre solution less attractive, whilst, on the other hand, conventional, wavelength selective wavelength division multiplexing and demultiplexing components are relatively complex and expensive.

The present invention is based on the appreciation that an optical fibre can be provided with a core and two or more claddings of progressively reduced refractive indices such that the cladding to the core becomes itself a core surrounded by the next outer cladding, and that these can be used for transmission at different wavelengths.

Preferably, the core is a monomode core for high bandwidth transmission while the further core formed by the cladding to the core in combination with its own cladding forms a multimode core with a relatively low transmission bandwidth.

Thus, whereas the downstream bandwidth of an interactive CATV system will have to be of the order of 100M bit/s to several 100M bit/s to accommodate at least one, and advantageously several, broadcast quality television channels, the upstream bandwidth requirement even in a highly

developed system will be much smaller. A reduced standard video channel (for example, for some form of visual telecommunications) is the most that can reasonably be envisaged and such a channel might require only up to 10M bit/s.

Apart from being used in interactive systems having a high bandwidth forward channel and a narrow bandwidth return channel, the present invention permits forward transmission in both core and further core whereby the further core may be used for example, to transmit telemetry and other control signals.

The invention will now be explained further by way of example and with reference to the accompanying drawings of which:—

Figure 1 is a diagram of an interactive system according to the present invention;

Figure 2 illustrates various alternatives for obtaining the fibre structure of Figure 1;

Figure 3 illustrates in diagrammatical form alternative embodiments of subscriber end transceiver devices; and

Figure 4 is a schematic diagram of a head-end transceiver device.

Referring first to Figure 1, the essential components of an interactive cable television system are an optical fibre, a head-end transceiver comprising a laser 4 and photodiode 5, and a subscriber end transceiver comprising a photodiode 6 and a light emitting diode 7. The head-end and subscriber end may, of course, be separated by one or more repeaters (not shown), and the head end itself may be co-located at a switching point in a star-structured system. Upstream of the switching point the required return channel bandwidth may be sufficiently large to justify one or more separate fibres for the return channel.

The fibre comprises a monomode core 1 and a monomode cladding 2 to a monomode core 1, and a further cladding 3 of a lower refractive index than the monomode cladding 2 so that the monomode cladding 2 forms a multimode core within the multimode cladding 3.

High bandwidth forward, or downstream, transmission is accomplished via the monomode core 1, the light being injected into the monomode core by a laser device 4 and received at the subscriber by a fast photodiode 6. Return, or upstream information is transmitted from the subscriber by means of a light emitting diode LED 7 and is launched into the cladding 2 of the monomode core 1, which, by being surrounded by the further cladding 3, constitutes a multimode core through which information can be transmitted back to the head-end (if necessary via one or more repeaters) where it is received by a photodiode 5.

Being of relatively narrow bandwidth, 10M bit/s say, as compared with the forward transmission bandwidth of greater than 100M bit/s, it is convenient to select a cheap LED transmitting device 7 for the return channel, with a return transmission wavelength in the 850nm wavelength range, while the forward transmission

will normally be in the 1.3 $\mu$ m or 1.5 $\mu$ m wavelength region.

In this form of wavelength division multiplexing is used, the monomode cladding 2, and/or the multimode cladding 3 may be arranged to provide selective attenuation of the appropriate one of the wavelengths used. This attenuation could be achieved by suitable doping during manufacture, or inclusion of greater amounts of water, or the like.

Various methods of achieving a suitable refractive index cross-section through the fibre are indicated by Figure 2. Thus, as shown in Figure 2a, the monomode core 1 may be heavily doped to have a higher refractive index than the more lightly doped monomode cladding 2 which also forms the multimode core and which itself is surrounded by a pure silica cladding 3 of yet lower refractive index. Alternatively, as shown in Figure 2b, the monomode core 1 may be lightly doped, the cladding 2 to the monomode core 1 may be of pure silica, and the further cladding may be doped with fluorine or other refractive index reducing dopants to have a yet lower refractive index than the monomode cladding 2.

A third alternative is illustrated in Figure 2c, in which the monomode core 1 is lightly doped, the cladding 2 to the monomode core 1 consists of pure silica, and the further cladding 3 to the multimode core 2 consists of silicone resin.

Referring now to Figure 3, there are shown in schematic form three alternative constructions for a subscriber transceiver device 6, 7. In each case the multimode transmitting light emitting diode 7 is arranged to form optically an annulus around the central photodiode 6. Depending on the transparency of the substrate 8 of the devices 6, 7, to the wavelengths concerned, several possibilities exist for implementing the annular structure, of which three are illustrated in the Figure 3.

As shown in Figure 3a, provided the substrate 8 is transparent to the wavelength  $\lambda_2$  of light emitted by the light emitting diode 7a, the light emitting diode 7a and the photodiode 6a can be arranged as shown on opposite sides of the substrate 8 with the photodiode 6a being installed nearest the optical fibre.

Another arrangement is shown in Figure 3b in which transparency of the substrate is not essential since both the photodiode 6b and the light emitting diode 7b are arranged substantially coplanar on the same side of the substrate 8.

In Figure 3c, the light emitting diode 7c has superimposed on it the photodiode structure 6c.

As an alternative to the annular structures shown in Figure 3, the photodiode 6a and the LED 7a may be simply laterally displaced with respect to each other, but may use otherwise similar configuration to those shown in Figure 3.

In all cases, the photodiode 6 and light emitting diode 7 may utilise known device structures.

In Figure 4 is shown a transceiver device arrangement for the head-end of the system, in which an annular photodiode 5a is arranged

concentrically about a laser transmitter 4a.

The laser 4 (and the photodiode 6 of Figure 1) are arranged to operate at a first wavelength  $\lambda_1$  of, for example, 1.3 $\mu$ m, and the photodiode 5 (and the light emitting diode 7) to operate at another wavelength  $\lambda_2$  of, for example, 850nm.

As an alternative, the transmitting laser and the receiving photodiode may be laterally displaced instead of forming the annular structure shown in Figure 4.

Repeaters for this system can be readily obtained by, essentially, back to back operation of the previously described head-end and subscriber end transceivers, with any necessary electronic circuitry being placed therebetween.

The present invention thus permits wavelength division multiplexing between the downstream and the upstream channel using the same fibre and yet avoids the need for complex wavelength selective multiplexing and de-multiplexing devices.

The present invention may also be used in applications such as, for example, remote video supervision, whereby high bandwidth picture information is transmitted via the core 1, and low bandwidth control information via core 2. In this case, the receiver devices for both wavelengths will be placed together, as will the transmitter devices.

Referring once more to Figures 1 and 2, it should be noted that the profile of the inner core 1, and/or the outer core 2 need not necessarily be stepped as shown in Figure 2, but may instead be suitably graded.

## CLAIMS

1. A wavelength division multiplexed optical fibre transmission system comprising a first transmitter and receiver and a second transmitter and receiver linked by an optical fibre, wherein the first transmitter and the second receiver operate at a first optical wavelength and the second transmitter and the first receiver operate at a second optical wavelength, and wherein the optical fibre has a core and a cladding about the core, and about said cladding a further cladding of a refractive index such that a further core is formed within said further cladding.

2. A wavelength division multiplexed optical fibre transmission system as claimed in claim 1 for interactive cable television, in which said first transmitter and receiver are at a node of the system and said second transmitter and receiver are at a subscribers premises, and in which the core serves to transmit high bandwidth information from the node to the subscriber and said further core serves to transmit low bandwidth information from the subscriber to the node.

3. A transmission system as claimed in claim 1 or claim 2 in which said core is capable of transmitting optical signals having wavelengths greater than 1  $\mu$ m and said further core is capable of transmitting optical signals having wavelengths of less than 1  $\mu$ m.

4. A transmission system as claimed in claim 1

or claim 2 in which said core is capable of transmitting optical signals having a wavelength from the range  $1.1\ \mu\text{m}$  to  $1.6\ \mu\text{m}$ , and in which said further core is capable of transmitting optical signals having a wavelength from the range 800 nm to 900 nm.

5 A transmission system as claimed in any preceding claim in which said core is arranged to transmit optical signals in the region of  $1.3\ \mu\text{m}$  or in the region of  $1.5\ \mu\text{m}$ , and in which said further core is arranged to transmit optical signals in the region of 850 nm.

10 6. A transmission system as claimed in any preceding claim in which said core is a monomode core and in which said further core is a multimode core.

15 7. A transmission system is claimed in any preceding claim in which said core and/or said further core are arranged to attenuate preferentially light of the second and the first wavelength respectively.

20 8. A transmission system as claimed in any preceding claim in which said first transmitter uses a coherent light source and in which said second transmitter uses an incoherent light source.

25 9. A transmission system substantially as hereinbefore described with reference to and as illustrated by the accompanying drawings.

30 10. A method of wavelength division multiplexing optical signals, the method comprising transmitting a modulated optical

signal of a first wavelength through an optical fibre having a core and a cladding, and transmitting a modulated optical signal of a second wavelength through a further core of the fibre, said further core being defined by a further cladding about said cladding.

35 11. A method of operating an interactive cable television system by wavelength division multiplexing of optical signals to and from a subscriber in accordance with the method as claimed in claim 10.

40 12. A method as claimed in claim 10 or claim 11 in which said first optical signal has a wavelength greater than  $1\ \mu\text{m}$  and said second optical signal has a wavelength of less than  $1\ \mu\text{m}$ .

45 13. A method as claimed in claim 12 in which said first optical signal has a wavelength in the range of  $1.1$  to  $1.6\ \mu\text{m}$ , and in which said second optical signal has a wavelength in the range 800 to 900 nm.

50 14. A method as claimed in claim 13 in which said first optical signal has a wavelength in the region of  $1.3\ \mu\text{m}$  or in the region of  $1.5\ \mu\text{m}$ , and in which said second optical signal has a wavelength in the region of 850 nm.

55 15. A method substantially as hereinbefore described with reference to the accompanying drawings.

60 16. An optical fibre substantially as hereinbefore described with reference to the accompanying drawings.